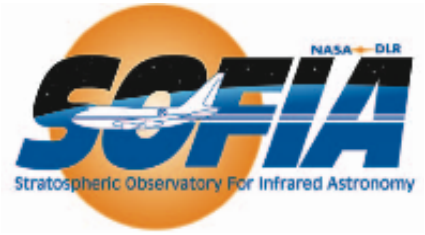
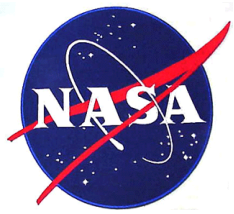


Vacuum Pump System (VPS) Specification

APP-DA-SPE-SE01-2049

Date: June 9, 2013
Revision: -



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Vacuum Pump System (VPS) Specification
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Vacuum Pump System (VPS) Specification

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Vacuum Pump System (VPS) Specification

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Revision History

SE01-2049 Rev. -

REV	DATE	DESCRIPTION	APPROVAL
	8/3/00	Initial release of Item Development Specification for the SOFIA Vacuum Pumping and Blower System (SP96162174-000).	8/7/2000 James Kephart
Draft A	9/1/09	Update to original Vacuum Pump and Blower Specification to Rev. A, intended to supercede the unbaselined SE01-028 specification draft. The original SE01-028 specification included both a vacuum pump system and blower system. The requirements have since been modified and the current specification includes only the vacuum pump system.	SPCB
-	5/9/13	Initial release of new document number SE01-2049 reflecting new VPS ConOps. New document is for VPS requirements only.	PPCB

Doc ID	Rev	Par ID	Text	SE01-004 Parent
SE01-2049	-	1	**Purpose and Subsystem Description**	
SE01-2049	-	1.1	**Purpose**	
SE01-2049	-		The purpose of this specification is to define the requirements for the Science Instrument (SI) Vacuum Pump System of the Stratospheric Observatory for Infrared Astronomy (SOFIA) Project. This system comprises one of the systems defined in the Airborne System Specification, SE01-004. The vacuum pump system must be airworthy and capable of supporting science instrument cryogenic dewars and telescope assembly instrument flange tub evacuation.	
SE01-2049	-		This specification replaces the unbaselined SE01-028 draft specification, "Item Development Specification for the SOFIA Vacuum Pumping and Blower System," which was submitted to but not approved by the Government. The original SE01-028 specification from August 2000 defined requirements for the SOFIA SI Vacuum Pump and Blower System. The system has since been changed to separate the vacuum pump and the blower. At the time of the writing of this document, no blower specification exists.	
SE01-2049	-		This specification does not attempt to define aircraft wiring or various "upstream" protections as may be required by safety considerations outside the vacuum system, power circuit protection, vibration, or ventilation.	
SE01-2049	-	1.2	**Subsystem Description**	
SE01-2049	-		A vacuum system is required for use by the mission operations team during flight. This vacuum system serves two purposes, to pump out the INF tub when needed, and to support in-flight vacuum requirements of the Science Instruments.	
SE01-2049	-		Select science instrument systems use detectors that require temperatures lower than the liquid helium (LHe) bath temperature of 4.2 K. In order to optimize detector response and noise level, it is necessary to pump on the LHe bath to lower the temperature to between 1.5 K and 2 K. The type of pump system required is a standard mechanical pump with sufficient pump speed and throughput such that a sufficiently low pressure can be achieved within a reasonable time. In addition, some instruments will require that their optical path be evacuated as part of onboard testing or as part of operations.	
SE01-2049	-		A context diagram depicting the VPS and applicable interfaces may be found as PM17-2074, VPS Concept of Operations, Figure 1.2-1.	
SE01-2049	-	2	**Applicable Compliance and Reference Documents**	

Doc ID	Rev	Par ID	Text	SE01-004 Parent
SE01-2049	-		The following ICDs, specifications and standards form a part of this specification to the extent specified herein. Configuration controlled documents will be the latest revisions available, unless otherwise stated as specific revisions.	
SE01-2049	-		Those documents that are cited as sources of mandatory requirements appear in the Compliance Documents section. These are applicable to VPS design and development activities performed in-house or outsourced by the VPS developer.	
SE01-2049	-		Those documents that are cited as sources of recommended guidelines or for reference only appear in the Guidance / Reference Documents section.	
SE01-2049	-	2.1	**Precedence**	
SE01-2049	-		In the event of a conflict between the text of this document and the referenced documents cited herein, the text of this document takes precedence. Nothing in this document, however, supercedes the contractual requirements unless a specific exemption has been obtained and approved. As appropriate, reference is made to other project documentation for use as guidance in developing the content of this document and as such forms a basis for requirements to the extent specified herein.	
SE01-2049	-	2.2	**Compliance Documents**	
SE01-2049	-	2.2.1	**Interface Control Documents (ICDs)**	
SE01-2049	-		SOF-DF-ICD-SE03-018 (TA_AS_11), TA Assembly / Aircraft System Exhaust Tube and Vacuum Line(s) Interface	
SE01-2049	-		SOF-DA-ICD-SE03-036 (TA_SI_01), Cable Load Alleviator Device / Science Instrument Cable Interface	
SE01-2049	-		SOF-DA-ICD-SE03-037 (TA_SI_02), Telescope Assembly / Science Instrument Mounting Interface	
SE01-2049	-		SOF-DA-ICD-SE03-2022 (VPS_SI_01), Vacuum Pump System to Science Instrument ICD	
SE01-2049	-		SOF-DF-ICD-SE03-048 (TA_MCCS_P), Telescope Assembly to Mission Controls and Communications System (MCCS) Physical Interface	
SE01-2049	-		APP-DF-ICD-SE03-TBD (VPS_AS_01), Vacuum Pump System to Aircraft System Interface	
SE01-2049	-		SOF-AR-ICD-SE03-2029 (MCCS_SI_05), Principal Investigator Patch Panel to Principal Investigator Equipment Rack(s) ICD	
SE01-2049	-		APP-DF-ICD-SE03-2038, Global Power Budget ICD	
SE01-2049	-		APP-DF-LIS-SE03-2042, Platform Parameter List	
SE01-2049	-	2.2.2	**SOFIA Specifications and other Compliance Documents**	
SE01-2049	-		SOF-DF-SPE-SE01-004, SOFIA Airborne System Specification	3.1.26
SE01-2049	-		APP-DF-PLA-PM23-2000, SOFIA Airborne Platform Logistics Plan	

Doc ID	Rev	Par ID	Text	SE01-004 Parent
SE01-2049	-		PM11-001, NASA Public Use Airworthiness Certification Plan	
SE01-2049	-		USRA-DAL-1126-00, Structural Design Criteria for the Stratospheric Observatory for Infrared Astronomy (SOFIA) Program	3.4.16
SE01-2049	-	2.2.3	**Standards**	
SE01-2049	-		DCP-O-018, Environmental Acceptance Testing, Electronic and Electromechanical Testing	
SE01-2049	-		RTCA DO-160D, Environmental Conditions and Test Procedures for Airborne Equipment	
SE01-2049	-		MIL-STD-464A, Electromagnetic Environmental Effects Requirements for Systems, Para. 5.6	3.4.1
SE01-2049	-	2.3	**Guidance / Reference Documents**	
SE01-2049	-	2.3.1	**SOFIA Specifications and other Reference Documents**	
SE01-2049	-		APP-DA-PLA-PM17-2074, SOFIA Vacuum Pump System Concept of Operations	
SE01-2049	-		SOF-DF-PD-PD-2009, SOFIA Lexicon	
SE01-2049	-		SOF-SPE-KT-4000.0.02, Flange Assembly Description	
SE01-2049	-		APP-DF-PRO-OP02-2043, Procedure for Crossing the TA Barrier during Flight	
SE01-2049	-	2.3.2	**Standards**	
SE01-2049	-		MIL-STD-1472D, Human Engineering Design Criteria [Feb. 1994/Rev. D, Notice 3]	
SE01-2049	-		NPR 6000.1, NASA Requirements for Packaging, Handling, and Transportation [March 2005/Rev. G]	

Document ID	Rev	Par ID	Text	Rationale	Comments	V&V Method	SE01-004 Parents
SE01-2049	-	3.1.1	The Vacuum Pump System shall provide a separate circuit breaker for each vacuum pump circuit.	APP-DA-PLA-PM17-2074, VPS Concept of Operations, para. 2.2. Used for troubleshooting and isolation purposes.		Demo	3.1.26 3.1.28 3.1.29
SE01-2049	-	3.1.2	The vacuum pumps used within the Vacuum Pump System shall be of an oil-free design.	APP-DA-PLA-PM17-2074, VPS Concept of Operations, para. 2.2. Oil from an oil vacuum pump can back-stream into a science instrument or the tub, contaminating sensitive components of the SI or TA. This requirement also obviates the requirement that the vacuum pump exhaust be vented overboard to eliminate the hazard of oil contamination in the aircraft cabin. Numerous oil-		Inspect	3.1.26 3.5.3 3.10.4
SE01-2049	-	3.1.3	Each vacuum pump flowrate control shall have one absolute pressure gauge with a measurement range of 0 torr to 800 torr.	APP-DA-PLA-PM17-2074, VPS Concept of Operations, para. 2.1, 2.2, 2.4.2. Vacuum gauging is necessary for reference when adjusting the flowrate and for diagnostic purposes.		Demo	3.5.3 3.1.26
SE01-2049	-	3.1.4	Each vacuum pump shall have an electronic absolute pressure transducer with a measurement range of at least 1 to 800 torr.	APP-DA-PLA-PM17-2074, VPS Concept of Operations, para. 2.1, 2.2, 2.4.2. Measurement of the pressure should be made as close as is practical / possible to the point that is being monitored or controlled (i.e., for the VPS, this is close to the SI vacuum interface at the Counterweight Plate, as defined in SE03-2022 Figures 2 and 3.). All relevant pressures are greater than 1 torr. Note this data will be available to SI teams through MCCS housekeeping		Inspect	3.5.3 3.1.26

Document ID	Rev	Par ID	Text	Rationale	Comments	V&V Method	SE01-004 Parents
SE01-2049	-	3.1.5	The Vacuum Pump System shall include a manually actuated isolation valve between each vacuum pump and its associated vacuum line.	APP-DA-PLA-PM17-2074, VPS Concept of Operations, para. 2.1, 2.2, 2.4.1, 2.4.2. Allows isolation of subsystems and components for troubleshooting and maintenance activities. Allows maintenance, change-out or swapping of vacuum pumps without venting the evacuated volume to cabin pressure. Also allows venting of the vacuum lines and/or the evacuated volume (i.e., for reseating of seals, rerouting of lines, etc.) without cycling the vacuum pumps, which can lead to degradation of performance and more frequent servicing. The electrically actuated valve specified in the following requirement paragraph could potentially satisfy this requirement if that valve includes a manual over-ride function that allows it to be closed and opened independently of the		Inspect	3.5.3 3.1.26
SE01-2049	-	3.1.6	The Vacuum Pump System shall include an isolation valve that closes upon removal of power to the pump.	APP-DA-PLA-PM17-2074, VPS Concept of Operations, para. 2.2. It is necessary to automatically and quickly isolate the pump(s) from the vacuum lines to prevent an uncontrolled backflow into the evacuated volume in the event of an unplanned power outtage or pump failure.		Inspect Demo	3.5.3 3.1.26
SE01-2049	-	3.1.7	The Vacuum Pump System shall include a bleed valve for each pump to vent the pump to cabin pressure independently of the vacuum line.	APP-DA-PLA-PM17-2074, VPS Concept of Operations, para. 2.3. This will enable the pump to be worked on without venting the entire vacuum system.		Inspect	3.5.3 3.1.26
SE01-2049	-	3.1.8	The Vacuum Pump System shall include a bleed valve for each vacuum line to vent the line to cabin pressure independently of the vacuum pump.	APP-DA-PLA-PM17-2074, VPS Concept of Operations, para. 2.3. This will enable work on the vacuum system without having to shut down the pump and vent the entire system.		Inspect	3.5.3 3.1.26
SE01-2049	-	3.1.9	The Vacuum Pump System shall include 2 valves to isolate the vacuum lines from the INF Vacuum / Vent Line Interface KF-25 flanges defined in ICD TA_SI_02 (SE03-037) Para. 4.5.3 and Fig. 4-8.	APP-DA-PLA-PM17-2074, VPS Concept of Operations, para. 2.1, 2.2, 2.4.1. The INF and/or SI-provided pressure coupler can be left with its interior evacuated when the vacuum pumps are powered down and/or the vacuum lines are vented and disconnected in support of instrument or platform operations.		Inspect	3.5.3 3.1.26

Document ID	Rev	Par ID	Text	Rationale	Comments	V&V Method	SE01-004 Parents
SE01-2049	-	3.1.10	The Vacuum Pump System shall support two (2) simultaneous but distinct vacuum pumping operations (i.e., two separately controllable vacuum pumps).	APP-DA-PLA-PM17-2074, VPS Concept of Operations, para. 2.2, 2.3, 2.4.2. It will be necessary at some point to pump on two cryogen baths at the same time or a cryogen bath and the INF. This also supplies a ready back-up when only a single system is needed.		Demo	3.5.3 3.1.26
SE01-2049	-	3.1.11	The Vacuum Pump System shall include a vacuum line, routed between an INF Vacuum / Vent Line Interface KF-25 flange defined in ICD TA_SI_02 (SE03-037) Para. 4.5.3 and Figure 4-8, and the Pump Lines interface KF-40 flange defined in ICD VPS_SI_01 (SE03-2022) Section 5.2 and Figures 2 and 3	APP-DA-PLA-PM17-2074, VPS Concept of Operations, para. 1.2, 2.4.1. Vacuum line to be routed per SE03-037 (TA_SI_02) Section 4.6.		Inspect	3.5.3 3.1.26
SE01-2049	-	3.1.12	The Vacuum Pump System shall support deployment and operate out of approved remote sites around the world for a minimum of 14 days and a goal of up to 60 days.	Requirement for portability greatly increases the amount science data the SOFIA can collect over its lifetime. Coverage of both the northern and southern hemispheres increases SOFIA's science return. This requirement also leads to site surveys in order to verify the system can be properly operated at the deployed site. This requirement envelops the PCA requirement that states that the Airborne Observatory will be capable of global operations. The goal of 60 days is driven by infrastructure at the deployment site.		Analysis	3.1.10

Document ID	Rev	Par ID	Text	Rationale	Comments	V&V Method	SE01-004 Parents
SE01-2049	-	3.1.13	The Vacuum Pump System shall provide interoperability between the two vacuum pumps supporting two simultanous pumping operations.	APP-DA-PLA-PM17-2074, VPS Concept of Operations, para. 2.1, 2.2, 2.4.2. Either vacuum pump needs to be capable of pumping the vacuum lines to the SI or the INF tub. With the concurrence of Platform Project Operations Engineering, this interoperability may be implemented via inflight reconfiguration of KF flange connections between the vacuum pumps, vacuum lines and/or manifolds, in the event of an off-nominal situation such as a pump or vacuum line failure. Note that if this approach is pursued, procedures should acknowledge and mitigate the risk of FOD associated with the KF fitting components (e.g., clamps, o-ring seal centering ring assemblies). This approach should NOT be implemented using the KF fittings at the CWP or INF due to accessibility issues and the risks of introducing		Demo	3.5.3 3.1.26 3.5.32
SE01-2049	-	3.2.1	Each vacuum pump shall support a pumping flowrate (He gas) of at least 550 liters/minute at 10.126 torr.	APP-DA-PLA-PM17-2074, VPS Concept of Operations, para. 2.4.2, Appendix B. This is the pumping rate needed to overcome the He boil-off as the LHe bath goes through the lambda point in the FIFI-LS use case within the ConOps.		Analysis Demo	3.1.26
SE01-2049	-	3.2.2	Each vacuum pump shall evacuate the volume of the Instrument Flange (INF) to 22.5 torr in 90 min, with an additional leak load of 0.3 liters/second.	APP-DA-PLA-PM17-2074, VPS Concept of Operations, para. 2.1, 2.2, 2.4.1, 2.4.3. Some science instruments require an evacuated internal optical path as part of operations or onboard testing. The combined volume of the instrument and INF will be less than three time that of the INF interior. A leak rate has been incorporated into this requirement as the system will have both real and virtual (trapped volume) leaks.		Analysis Test	3.1.26
SE01-2049	-	3.2.3	The Vacuum Pump System flowrate controls shall be continuously controllable over the range of zero to 550 liters/minute.	APP-DA-PLA-PM17-2074, VPS Concept of Operations, para. 2.4.2, Appendix B. Flowrate must be modulated as the bath temperature is reduced below 4.2 K to minimize the loss of cryogens that would result in reduced instrument operation time.		Analysis Demo	3.1.26 3.5.3

Document ID	Rev	Par ID	Text	Rationale	Comments	V&V Method	SE01-004 Parents
SE01-2049	-	3.2.4	The pressure gauges on each vacuum pump shall each have an accuracy of ≤ 0.33% of full scale pressure, and a scale w/ graduations no greater than ≤ 0.2% of full scale pressure.	APP-DA-PLA-PM17-2074, VPS Concept of Operations, para. 2.4.2, Appendix B. VPS pressures must be measurable with accuracy and precision needed to allow operator to effect required temperature control of LHeII cryogen bath within the 1.6 ~ 1.8 K range		Inspect	3.1.26 3.5.3
SE01-2049	-	3.2.5	The electronic pressure transducer on each vacuum pump line shall have an accuracy of ≤ 1% of the current reading, a precision (resolution) ≤0.02% of full scale pressure, and a repeatability within ±0.03% of full scale pressure.	APP-DA-PLA-PM17-2074, VPS Concept of Operations, para. 2.4.2, Appendix B. Accurate, precise and repeatable vacuum gauging is necessary for reference when adjusting the flowrate and for diagnostic purposes.		Inspect	3.1.26 3.5.3
SE01-2049	-	3.3.1	The Vacuum Pump System shall have independent operator adjustable pumping flowrate control for each vacuum pump and vacuum line.	APP-DA-PLA-PM17-2074, VPS Concept of Operations, para. 2.2, 2.3, 2.4.2. It will be necessary at some point to pump on two cryogen baths at the same time or a cryogen bath and the INF. This also supplies a ready back-up when only a single system is needed.		Inspect	3.5.3 3.1.26
SE01-2049	-	3.3.2	The Vacuum Pump System vacuum lines, including those between the pumps and the CLA Disconnect Panel shall have an inner diameter (ID) of 1.25 inch (31.75 mm) or greater	APP-DA-PLA-PM17-2074, VPS Concept of Operations, para. 2.2. Free-flowing, large diameter tubing will minimize pressure drop in tubing runs and interconnection fittings. Matches Chemfluor PTFE vacuum service convoluted hose specified and in place in CLA per SE03-036 and SE03-018. Existing equipment on the platform.		Inspect	3.5.3 3.1.26
SE01-2049	-	3.3.3	The Vacuum Pump System vacuum lines shall be flexible, vacuum rated, solid homogeneous PTFE extrusion, steel braid jacketed tubing.	APP-DA-PLA-PM17-2074, VPS Concept of Operations, para. 2.1. Solid homogeneous PTFE extrusion tubing has no seams or laminations that can create virtual leaks. Steel braid jacketing provides abrasion and crush resistance. Matches Chemfluor PTFE vacuum service convoluted hose specified and in place in CLA per SE03-036 and SE03-018. Existing equipment on the platform.		Inspect	3.5.3 3.1.26

Document ID	Rev	Par ID	Text	Rationale	Comments	V&V Method	SE01-004 Parents
SE01-2049	-	3.3.4	The Vacuum Pump System controls (power switch and pump flowrate controls) shall be accessible to the Mission Crew during flight and ground operations without involving the crossing of any safety barriers for access.	APP-DA-PLA-PM17-2074, VPS Concept of Operations, para. 2.2, 2.4.2. Adjustments to the vacuum system will need to be done when an instrument is in operation (line-ops and flights) so the controls must be accessible without the need to invoke the constraints of APP-DF-PRO-OP02-2043, Procedure for Crossing the TA Barrier during Flight.		Inspect	3.5.3 3.1.26
SE01-2049	-	3.3.5	The electronic pressure transducers on each vacuum line shall sense pressure at the KF16 flange as defined in ICD VPS_SI_01 (SE03-2022) Para 5.2b and Figure 3.	This is as close as we can reasonably expect the VPS to measure pressure		Inspect	3.5.3 3.1.26
SE01-2049	-	3.3.6	The Vacuum Pump System shall include a debris screen or filter at the inlet to each vacuum pump.	Certain vacuum pump failures could deposit debris into the vacuum line contaminating the VPS system and/or upstream TA and SI systems.		Inspect	3.5.3 3.1.26
SE01-2049	-	3.4.1	The Vacuum Pump System shall be designed to minimize Electromagnetic Interference (EMI) and maximize Electromagnetic Compatibility.	Safety and mission success can be adversely affected by EMI. Demonstrated and verified during CST at SE01-004 level.		Inspect	3.4.1
SE01-2049	-	3.4.2	The Vacuum Pump System equipment shall meet the non-operating steady state temperature requirements in accordance with DCP-O-018 Section 8.2.	DCP-O-018 defines the environmental conditions the Airborne System is expected to endure during the 20 year life of the program. May need to waive some specific environmental range requirements if cost is excessive and lesser ranges will be adequate.		Inspect	3.4.17
SE01-2049	-	3.4.3	The Vacuum Pump System equipment and installations shall operate in the vibration environment in accordance with DO-160D, Figure 8-2, Curve C1.	DO-160D Curve C1 defines the vibration loads in the main cabin that the Airborne System is expected to endure during the 20 year life of the program. This requirement excludes Ground Support Equipment.		Inspect Test	3.4.15
SE01-2049	-	3.4.4	The Vacuum Pump System shall operate after exposure to the non-operating temperature conditions in accordance with DCP-O-018 section 7.2.	DCP-O-018 defines the environmental conditions the Airborne System is expected to endure during the 20 year life of the program. May need to waive some specific environmental range requirements if cost is excessive and lesser ranges will be adequate.		Inspect Analysis	3.4.19

Document ID	Rev	Par ID	Text	Rationale	Comments	V&V Method	SE01-004 Parents
SE01-2049	-	3.4.5	The Vacuum Pump System equipment shall meet the performance requirements specified herein while exposed to the humidity environment defined in DO-160D, Paragraph 6.0 Category A, Standard Humidity Environment.	This is a direct reference to humidity environment (95% relative humidity) that the aircraft will be exposed to. This requirement excludes Ground Support Equipment.		Inspect Analysis	3.4.18
SE01-2049	-	3.4.6	VPS equipment installations shall meet the applicable load requirements in accordance with USRA-DAL-1126.	A SOFIA Program decision was made to follow a NASA self certification process. This decision was made due to the one-of-a-kind nature of the Airborne Observatory. Also, it is believed that self certifying would be more appropriate than using the FAA certifying process. A certificate of airworthiness is required to fly within US and international airspace. This requirement excludes Ground Support Equipment.		Analysis	3.4.16
SE01-2049	-	3.4.7	The Vacuum Pump System shall implement Electrical bonding measures in accordance with NAVAIR 01-1A-505-1 Work Package 17 procedures and processes.	Electrical bonding measures ensure required system performance and to protect personnel. Bonding provisions will be compatible with other requirements imposed on the system for corrosion control. For further guidance see MIL-STD-464A.		Inspect Analysis	3.3.37 3.4.2
SE01-2049	-	3.4.8	The Vacuum Pump System shall meet the performance requirements specified herein for the operating pressure environments (altitude) of document DCP-O-018 section 9.	DCP-O-018 defines the loads the Airborne System is expected to endure during the 20 year life of the program. This requirement excludes Ground Support Equipment. May need to waive some specific environmental range requirements if cost is excessive and lesser ranges will be adequate.		Analysis Inspect	3.4.7
SE01-2049	-	3.4.9	The Vacuum Pump System shall operate in its intended operational electromagnetic environment in accordance with document DOP-O-401.	DOP-O-401 establishes and describes DFRC-specific electrical system requirements, methods, and procedures for installation, repair, rework, and maintenance that are not covered by T.O. 1-1A-14 (a USAF Technical Order entitled "Installation Practices for Aircraft Electrical and Electronic Wiring")		Demo	3.1.1 3.4.1

Document ID	Rev	Par ID	Text	Rationale	Comments	V&V Method	SE01-004 Parents
SE01-2049	-	3.4.10	The Vacuum Pump System equipment shall operate within the steady state temperature conditions of document DCP-O-018 section 8.2.	DCP-O-018 defines the environmental conditions the Airborne System is expected to endure during the 20 year life of the program. May need to waive some specific environmental range requirements if cost is excessive and lesser ranges will be adequate.		Analysis Inspect	3.1.1 3.4.17 3.4.19
SE01-2049	-	3.5.1	The Vacuum Pump System shall comply with the applicable NASA Public Use Airworthiness Certification processes using 14 CFR 25, MIL-STDs, and/or NASA standards.	A SOFIA Program decision was made to follow a NASA self certification process, utilizing FAA standards where applicable. This decision was made due to the one-of-a-kind nature of the Airborne Observatory. Also, it is believed that self certifying would be more appropriate than using the FAA certifying process. A certificate of airworthiness is required to fly within US and international airspace.		Analysis Inspect	3.5.3
SE01-2049	-	3.5.2	The Vacuum Pump System equipment installations shall guard personnel from surface temperatures which could cause burns and injury except for surface temperatures induced by climatic environments.	Where VPS equipment operating surface temperatures may cause burns or injury to personnel, proper protection will be provided.		Inspect Analysis	3.9.1
SE01-2049	-	3.5.3	Multiple connectors in the same area shall be unique in size, keyed separately and or uniquely labeled at the connector and on the mating surface.	This is good engineering practice from T.O. 01-1A-14.		Inspect	3.9.1
SE01-2049	-	3.5.4	The Vacuum Pump System shall be subject to a hazard Analysis per DCP-S-002.	This requirement promotes safe operation and protects personnel and equipment.		Inspect	3.5.30
SE01-2049	-	3.5.5	The Vacuum Pump System connectors shall incorporate locking features or provisions for safety wire.	Only applicable to good engineering practice from T.O. 01-1A-14.		Inspect	3.5.3 3.5.30
SE01-2049	-	3.6.1	The Vacuum Pump System shall support least 12 hours of continuous operation.	APP-DA-PLA-PM17-2074, VPS Concept of Operations, para. 2.1, 2.2, 2.4.2. The VPS must be capable of supporting SIs for a complete mission.		Analysis	3.1.1 3.2.4

Document ID	Rev	Par ID	Text	Rationale	Comments	V&V Method	SE01-004 Parents
SE01-2049	-	3.7.1	Each vacuum pump shall be mounted such that it can be swapped with a replacement pump within 3 hours or less.	APP-DA-PLA-PM17-2074, VPS Concept of Operations, para. 2.3. Vacuum pump should be replacable between flights.		Analysis Demo	3.7.6 3.2.4 3.7.12
SE01-2049	-	3.7.2	The Vacuum Pump System shall allow for the maintenance required for continuous airworthiness.	APP-DA-PLA-PM17-2074, VPS Concept of Operations, para. 2.3. The VPS will allow ease of maintainability for new mission systems in order to achieve the 960 hr. per year requirement.		Inspect	3.7.12
SE01-2049	-	3.7.3	Vacuum Pump System specific inputs to the SOFIA Airborne Systems spares and logistics plan shall be developed.	APP-DA-PLA-PM17-2074, VPS Concept of Operations, para. 2.3. This requirement ensures that at the lower levels the necessary durability and longevity are designed into the hardware. The anticipated annual science return of SOFIA necessitates 20-years of operations to justify the overall costs for development and operation of the facility.		Analysis	3.7.6
SE01-2049	-	3.8.1	The Vacuum Pump System shall identify any special tools required for maintenance and inspection, in the Airborne Platform Logistics Plan (PM23-2000).	APP-DA-PLA-PM17-2074, VPS Concept of Operations, para. 2.3. Special tools need to be identified and procured for maintenance.		Inspect	3.7.12
SE01-2049	-	3.8.2	The Vacuum Pump System shall be designed to allow packaging and shipment in accordance with NPR 6000.1G.	Transporting the Vacuum Pump System is likely necessary over the course of the Observatory's projected 20 year service life.		Inspect	3.8.1
SE01-2049	-	3.9.1	The Vacuum Pump System equipment designs, equipment modifications should comply with Human Engineering (MIL-STD-1472F Chg. 1 dated 12/5/03). (LOPA)	All SOFIA System components will be consistent with good human factors practices. Military Standard is a guidance document.		Inspect	3.9.1
SE01-2049	-	3.9.2	The Vacuum Pump System gauges shall be viewable by an operator adjusting the corresponding manual flowcontrol valves.	APP-DA-PLA-PM17-2074, VPS Concept of Operations, para. 2.2, 2.4.2. The operator adjusting the manual flowcontrol valve needs to monitor the corresponding guage while doing the adjusting.		Demo	3.9.1

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SE01-2049	-	3.10.1	The Vacuum Pump System design shall select parts, materials, and processes using best commercial aircraft industry practices as determined by Critical Design Review and airworthiness expert(s).	Required to meet NASA public Use Airworthiness certification process (SE01-003/3.5.5) MAPTIS II does not specify requirements. The MAPTIS-II system contains physical, mechanical and environmental properties for metallic and non-metallic materials. The MAPTIS rates materials based on suitability for the application and defines the criteria for the rating. If the material is not found in the A-rated MAPTIS (universal suitability), then the material selected needs to pass the flammability test outlined in NASA-STD-6001.		Inspect	3.5.3 3.10.8
SE01-2049	-	3.10.2	The Vacuum Pump System design shall include a protective plating or coating to all metal surfaces which are not corrosion resistant, except where electrical grounding is required.	This requirement excludes Ground Support Equipment. This reqmt pertains to components that may not have corrosion protection.		Inspect	3.10.2
SE01-2049	-	3.10.3	The Vacuum Pump System design shall not use materials which through out-gassing cause the deterioration of other materials or the degradation of performance of onboard equipment.	Required to meet NASA public Use Airworthiness certification process (SE01-003/3.5.5) MAPTIS II does not specify requirements. The MAPTIS-II system contains physical, mechanical and environmental properties for metallic and non-metallic materials. The MAPTIS rates materials based on suitability for the application and defines the criteria for the rating. If the material is not found in the A-rated MAPTIS (universal suitability), then the material selected needs to pass the flammability test outlined in NASA-STD-6001.		Inspect	3.10.4

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SE01-2049	-	3.11.1	The Vacuum Pump System shall operate as specified herein within the power allocation defined in SE03-2038, Global Power Budget ICD.	This is the Platform PCB-controlled ICD that defines the SOFIA observatory power bus and power allocated to the VPS. PMB-controlled ICD SE03-2029 (MCCS_SI_05) para. 3.2.1.3 includes additional information re: the location of the power drops and AWG sizing of the conductors from the PDS to the VPS power interface.		Inspect	3.1.42 3.3.20
SE01-2049	-	3.11.2	The Vacuum Pump System shall comply with ICD TA_AS_11 (SE03-018) Section 3.1.1 and Figures 3.1.3-1 and 3.1.3-2.	The ICD defines the interface to the vacuum lines that are routed through the CLA.		Inspect	3.1.29
SE01-2049	-	3.11.3	The Vacuum Pump System shall comply with TA_SI_02 (SE03-037).	The VPS vacuum lines will use KF-25 flange fittings, centering rings and clamps as defined in TA_SI_02 (SE03-037) Para. 4.5.3 and Fig. 4-8. Physical support and tubing relief will be provided for per Section 4.6.		Inspect	3.1.29
SE01-2049	-	3.11.4	The Vacuum Pump System vacuum lines, connecting to the SI, shall interface as defined in VPS_SI_01 (SE03-2022) Sections 5.2 and 5.3, and Figures 2 and 3.	This ICD defines the VPS-to-SI interface at the CWP.		Inspect	3.1.29
SE01-2049	-	3.11.5	The Vacuum Pump System shall interface with with ICD TA_SI_01 (SE03-036).	The transducer power and signal interface is identified in TA_SI_01 for the TA side of the CLA.		Inspect	3.1.29
SE01-2049	-	3.11.6	The Vacuum Pump System shall interface with ICD TA_MCCS_P (SE03-048).	The transducer power and signal interface is identified in TA_MCCS_P for the aircraft side of the CLA.		Inspect	3.1.28 3.1.29
SE01-2049	-	3.11.7	The Vacuum Pump System shall interface with the aircraft in accordance with ICD VPS_AS_01 (SE03-TBD).	This is the VPS phyiscal interface with the aircraft.		Inspect	3.1.28
SE01-2049	-	3.11.8	The Vacuum Pump System shall provide the output of each electronic pressure transducer to the MCCS in accordance with the Platform Parameter List (SE03-2042).	Transducer output is necessary for housekeeping data.		Test	3.1.20